

THE DARK RING IN SOUTHWESTERN LUNAR ORIENTALE BASIN: ORIGIN AS A SINGLE PYROCLASTIC ERUPTION.

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Background and Description: A large, 154 km diameter dark ring, located in the southwestern part of the Orientale Basin along the Montes Rook ring, was first discovered and documented in Zond 8 images. The feature appears as a dark circular deposit that mantles some of the massifs of the outer part of the Rook Mountain ring of the Orientale basin consisting of two arcs of dark material that are bisected by the bright inward facing massifs of the Rook Mountains. Individual massifs and hills of the Orientale basin deposits protrude through the dark ring or are incompletely covered by ring deposits. Additional Lunar Orbiter images led to the interpretation that the ring mantled both the hummocky inter-ring deposits and the fissured and corrugated Maunder Formation of the Orientale Basin [1]. Schultz and Spudis [2] noted that the materials of the ring were not evenly distributed and that they were often locally concentrated. They further pointed out that Montes Rook were discontinuous in the area of the ring (Figure 1) and that a part of the Montes Rook extends to the north into the basin for about 60 km along the western part of the dark ring and they suggested that the unusual massif topography could represent the presence of a large, pre-Orientale basin impact crater spanning the Rook Mountain ring. The implication of their interpretation was that the transient cavity rim crest of the Orientale impact basin lay inside the outer Rook Mountain ring [2]. Citing the common occurrence of annular volcanic vents in craters that have been modified volcanically [e.g., 3], Schultz and Spudis [2] suggested that the dark halo deposit was produced by several vents aligned along pre-existing zones of weakness associated with the pre-Orientale basin. Thus, in this interpretation, the deposit was produced by a large number of post-Orientale individual volcanic eruptions localized into a circular annulus by the influence of pre-existing (and pre-Orientale) impact crater/basin structure. Galileo images provided the first multispectral data of the dark halo deposit itself and analyses revealed spectra implying a pyroclastic deposit contaminated with the underlying highlands [4, 5]; Greeley et al. [4] supported the conclusion that the deposit was emplaced as a series of pyroclastic eruptions using reactivated fractures associated with the ancient basin proposed by Schultz and Spudis [2] as conduits. In summary, prior to Clementine the low albedo circular feature was interpreted as a ring of localized dark mantle deposits formed at vents located at the position of an ancient pre-Orientale-basin impact crater scar [2].

We have analyzed the deposit and its surrounding region using Clementine data and find information that supports a different interpretation. First, we have located and mapped an elongate 7.5 km by 16 km depression lying in the center of the dark ring. This feature was obscured in

previous images but is clearly shown in the Clementine data (Figure 1). It is unusual in terms of its morphology in that it is relatively rimless, is not associated with any other craters that might suggest that it was part of a secondary cluster and it is not specifically morphologically or stratigraphically associated with any deposits of the Orientale Basin [e.g., 1]. On the basis of our analysis, we interpret it to be a collapse depression and investigate the possibility that it is the location of a source vent for the dark ring deposit. Secondly, we are struck with the similarity of the dark ring deposit to deposits mapped on the Galilean satellite Io that form from eruptions generating pyroclastic plumes [6]. Using these concepts, theoretical treatment of the ascent and eruption of magma on the Moon [7], and multispectral data from the Clementine mission, we test the hypothesis that the dark ring is the manifestation of a pyroclastic eruption originating at a central vent, in a mode similar to that observed in the pyroclastic rings on Io.

Development of Model and Clementine Analysis: We model the eruption as involving a dike emplaced to within about 3-4 km of the surface which stabilized and degassed to form an upper foam layer (Figure 2). With time, the foam buildup caused overpressurization and roof failure, causing penetration of a crack to the surface, and evacuation of the foam reservoir at the top of the dike to cause an eruption. On the basis of our analysis [7], the eruption could produce a symmetrical spray of pyroclasts into the lunar vacuum at velocities of ~420 m/s (Figure 3). In the lower part of the plume, pyroclasts would be closely spaced and decompression isothermal. In higher parts of the plume, decompression processes become adiabatic with thermal coupling between gas and pyroclasts decreasing. In the highest and most distal portions of the plume, particles become dispersed and drag forces are negligible; particles decouple from the gas and follow ballistic trajectories. After flight times of less than about 10 minutes, pyroclastic material would land and accumulate in a symmetrical ring around the vent. The geometry of accumulation caused the deposits to accumulate preferentially in a ring representing the material ejected at 45° [7]. Estimates of the thickness of the ring deposit suggest that its maximum value may be in the range of several meters. Our analysis implies that the eruption lasted for several months. The observed rimless collapse depression forms as the upper part of the foam layer is erupted, and wall material slumps inward to replace it (Figure 2). Clementine multispectral data confirm that the dark ring consists of glass similar to the pyroclastic glasses collected by the Apollo astronauts, and that the glasses are most closely related to those that comprise the Aristarchus Plateau.

Summary and Conclusions: New mapping using Clementine data shows detailed morphological and spectral characteristics of the Orientale dark mantle ring deposit. We interpret the newly discovered elongate depression in middle of deposit as a source vent and model the dark mantle ring as a deposit produced from an eruption emanating from the central elongate vent in an umbrella-shaped plume. We find that this model is plausible and consistent with the observational data, and we conclude that the dark mantle ring was formed when a dike was emplaced to the near-surface, underwent volatile formation and buildup to produce a foam layer at the top of the dike, leading to an eruption producing a symmetrical spray of pyroclasts into the lunar vacuum at velocities of ~ 420 m/s (Figure 3). After flight times of less than about 10 minutes, pyroclastic material landed and accumulated in a symmetrical ring around the vent, preferentially in a ring representing the material ejected at 45° [7]. The paucity of pyroclastic rings of this type on the Moon can be attributed to the low probability of a large number of dikes stalling at just the right depth (about 3-4 km) to create these eruption conditions [8]. Evidence for other dikes emplaced to similar but different enough depths to cause different surface eruption manifestations strengthens the likelihood that the Orientale dark halo originated in this manner [8]. The detailed characteristics of this ring provide important new insight into the emplacement of pyroclastics in the more regionally continuous lunar dark mantle deposits [9]. In addition, if this interpretation is correct, the utilization of this dark mantle ring as suggesting the location of an ancient large pre-Orientale crater is no longer necessary

and thus does not constrain the location of the transient cavity of the Orientale basin, as previously proposed [2].

References: 1] D. Scott et al. (1977) *USGS Map I-1034*; 2] P. Schultz and P. Spudis (1978) *LPS* 9, 1033; 3] P. Schultz (1976) *Moon*, 15, 241; 4] R. Greeley et al. (1993) *JGR*, 98, 17183; 5] C. Pieters et al. (1993) *JGR*, 98, 17127; 6] A. McEwen and L. Soderblom (1983) *Icarus*, 55, 181; 7] L. Wilson and J. Head (1981) *JGR*, 86, 2971; 8] J. Head and L. Wilson (1992) *Planet. Space Sci.*, 41, 719; 9] C. Weitz et al., this volume.

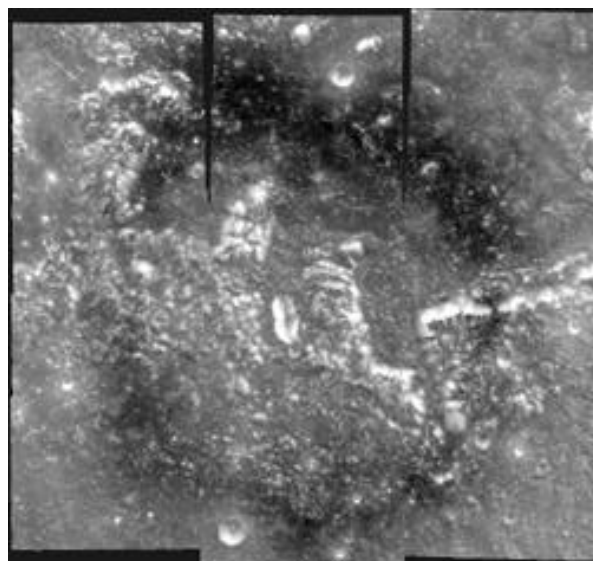


Figure 1.

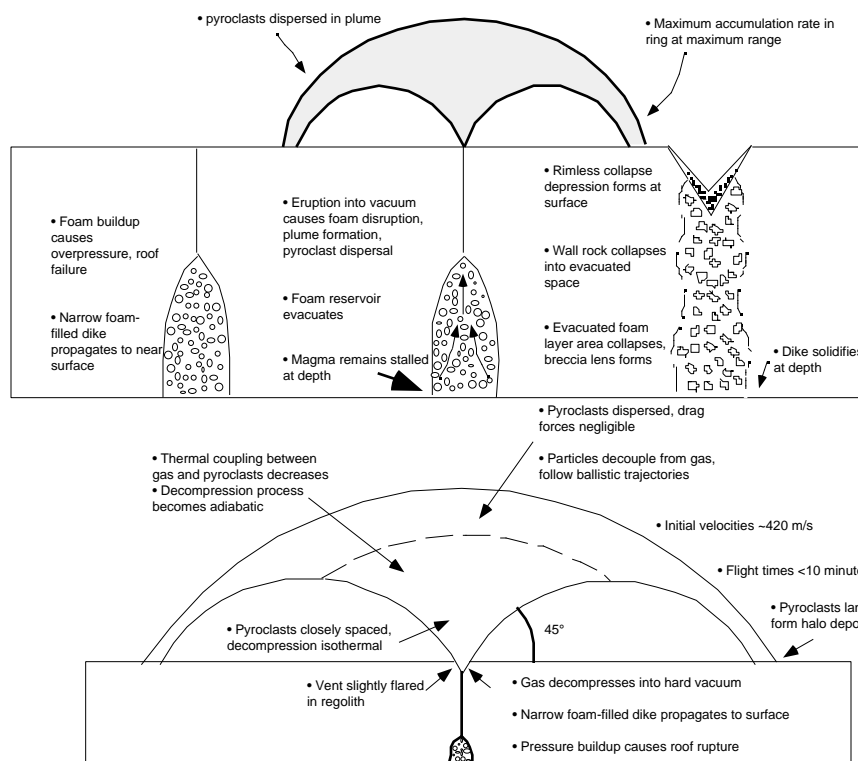


Figure 2.

Figure 3.